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Building form effects on energy efficient heat pump application for different climatic zones

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Abstract:
Energy efficiency in built environment remains the most important sustainable building issue, not only because of its environmental impacts but also the probability of significantly higher future energy costs. Optimized passive design integrated renewable energy systems can greatly reduce the energy consumption in buildings. In this study; in order to provide energy conservation and climatic comfort in buildings, an approach which aims to control the energy consumption of heat pumps in different climatic zones by controlling decisions related to building design parameters has been developed. For this purpose, four different building forms, namely square, rectangular, L-shaped and H-shaped which have the same floor area, volume and optical and thermophysical properties of building envelope are examined in temperate, hot and cold zones of Turkey by using a building simulation program, e-QUEST. Annual total heating and cooling energy consumptions of vertical loop ground and air source heat pump systems are calculated for every building form in temperate-dry, hot and dry and cold climatic zones.

Keywords: *Building form, heat pump, climatic zones, energy conservation, building energy simulation.*

1. Introduction

Creating a low energy profile while providing energy efficiency and climatic comfort is a major challenge for designers of sustainable buildings. Extracting and consuming non-renewable energy resources such as fossil fuels and nuclear energy have profound environmental and social implications.

A sustainable building should ideally use very little energy, and renewable energy should be the source of most of the energy needed for heating and cooling to minimize the energy consumption in buildings.

Heat pumps are one of the energy efficient systems which use renewable energy of a building's surroundings to provide heating and cooling in the building. They are classified by their heat sources such as; air, water and ground.

The performance of closed-loop ground heat exchangers is rather different than air coupled heat exchangers in that the primary heat transfer mechanism is conduction rather than convection. Using the ground as a heat source in an air conditioning system is attractive from a thermodynamic point of view, as its temperature is generally much closer to room conditions than the ambient dry bulb or wet bulb temperatures over the whole year. This results in both improved performance and increased capacity in extremely hot or cold climatic zones (Daniel et al. 2005, Summer 1976, Erdoğan et al. 2006).

Energy conservation in buildings can be achieved with heat pump systems by means of variables such as air temperature, mean radiant temperature, air movement and air humidity (Erdim, 2010). Heat pumps should be successfully implemented with the application of passive design parameters through the management of energy consumption in buildings.

The most important design parameters affecting indoor climate and energy consumption on a building scale are location, building form, orientation of the building and optical and thermophysical properties of the building envelope. All of these parameters are interrelated and the optimum value of each parameter should be determined depending on the values of the others (Koçlar &Yılmaz, 2003).

More recent research appears to focus on the issues of heat gain and loss and thermal comfort as a basis for formulating building form utilizing passive strategies on a different scale.

Lin showed that the energy consumption of a building depends on the building shape. In cold areas, the larger the external surface of the building, the more energy is used for heating; thus the optimum form of the building should have minimum external surface (Lin, 1981).

Depecker et al. studied the relationship between shape and energy requirements during the winter season in two French localities with different climate conditions, Paris and Carpentras (a town placed in southern France with a mild climate). In Paris they found a strong correlation between energy consumption and shape coefficient whereas in Carpentras they did not. So they did not give specific indications as far as the building design in mild climates is concerned. With regard to climatic conditions similar to those of Carpentras they asserted: “A link between the energy consumption of a building and its shape can no longer be stated. As a consequence, that leaves architects to choose any shape” (Depecker et al., 2001).

In another study, Mingfang found that the south is the optimum orientation of a building both for solar heat gain in the winter and solar heat control in the summer. Geometric shapes of buildings for solar control in the summer were discussed, and it was demonstrated that the optimum building proportion for solar control is a rectangular plan (Mingfang, 2002).

Yilmaz, Koclar and Manioglu discuss to determine the building form which ensures minimum heat loss throughout the whole building envelope. The building form is described by the indicator A/V (the ratio of total façade area to building volume). The heat loss is determined according to the U value of the building envelope. The building form which ensures minimum heat loss with a calculated limit U value is taken as the reference building form (A/V ratio).

The revised U values related to the reference building form are expressed with charts which help designers to revise building envelope U value for opaque component in order to achieve heating economy without changing other design parameters. Results confirm that especially in cold climates, the building form which is as close to the reference building form as possible should be selected (Yılmaz et al. 2000, Yılmaz et al. 2002).

Aksoy and Inalli studied the effects of passive parameters such as orientation positions and shape factors on the annual heating energy use of buildings. It is shown that buildings with a square shape have more advantages, and the most suitable orientation angles are 0°C and 80°C for the buildings with the shape factors (the ratio of building length to building depth) 2/1 and 1/2, respectively (Aksoy & Inallı, 2006).

Okeil was interested in developing a systematic comparison and an evaluation of the relationship between the urban building form and energy efficiency of three generic forms: two conventional forms and one proposed energy efficient form. The energy efficiency is evaluated in terms of solar exposure in winter and reduced heat gain in summer through the support of strategies for mitigating the urban heat island effect. The study shows that the approach can produce building forms that allow the maximum potential of passive utilization of solar energy in buildings to be reached and the newly developed building forms support strategies for mitigating the urban heat island effect through increased airflow, the promotion of marketable green roofs and the reduction of transportation energy (Okeil, 2010).

Zerefos et al., examine the energy consumption behavior of buildings in Mediterranean climates, which have polygonal and prismatic envelopes. Especially, the study aims to investigate the differences in energy consumption of these kinds of buildings compared to orthogonal building envelopes. For this purpose, a contemporary building was chosen and modelled in two different versions, one was the original prismatic form and the other was a model of the same building with right angles, however retaining all area and volume data of the original prismatic building. Calculations revealed that the building with the prismatic form has lower solar gains compared to its orthogonal counterpart and consumes less energy in an annual cycle (Zerefos et al., 2012).

Climatic comfort conditions cannot be met by only passive systems in a given period of the year. In order to reach the required climatic comfort conditions, supplementary heating and cooling systems becomes necessary. If a supplementary system is required for a building, the amount of energy which will be used in that system depends on the thermal performance of the passive design system. The building form affecting thermal comfort of the building influences the total heat loss and gain of the whole building. The façade area of the building and consequently the amount of heat flow through it can be altered due to the change in the building form. Moreover the orientation of the building form is the indicator of the amount of heat gained from solar radiation through building envelope. Thus, the amount of heat gained from solar radiation in the building volume is a function of the direction of the façades. Therefore the building form is the basic determinant of the indoor climate and also of the amount for supplementary energy consumption (Yılmaz, 1988).

Building form can be defined with the shape factor (the ratio of building length

to building depth), height and roof type. It is possible to determine a lot of building forms that yield the same volume, but with a different façade area. As is known, total heat loss changes with the form of a building even if the floor area remains the same. The most appropriate building form and heat pump alternative should be chosen according to the heating and cooling energy consumption. In order to minimize energy consumption and to determine the most energy efficient combination among the alternatives, an approach aiming to provide climatic comfort should be followed (Yılmaz et al., 2000).

This study aims to measure the impacts of energy efficient design parameters on energy consumption. Moreover, the study goes further to examine the energy consumption of the buildings which incorporate renewable energy systems. For this purpose, a methodology which aims to control the energy consumption of heat pumps by controlling the decisions related to building design parameters has been developed. The study aims to evaluate the effect of building design parameters and climatic conditions on energy-efficient heat pump applications. In this study, annual energy consumptions of different building forms such as square, rectangular, L-shaped and H-shaped which have the same floor area, volume and, optical and thermophysical properties of building envelope are studied and the results are analysed in terms of energy conservation. To gain better understanding about the relations between climatic conditions, building forms, heat pump systems and buildings' energy demand, three locations with different climatic conditions are chosen. The methodology is used in Ankara, Diyarbakir, and Erzurum which are representative cities of Turkey for temperate-dry, hot-dry and cold zones respectively.

2. The methodology

This study aims to evaluate the performance of different building forms with the use of heat pumps to provide climate comfort and energy conservation. For this purpose, the annual energy consumption of air source and ground source heat pump application are calculated for four different building forms which have the same floor area, volume and, optical and thermophysical properties of the building envelope. The proposed methodology is used in Ankara, Diyarbakir and Erzurum which are representative cities of Turkey for temperate-dry, hot-dry and cold zones respectively. As a result of these calculations, the optimum building form and heat pump combination which has the minimum energy consumption is proposed for every climatic zone by comparing the annual heating and cooling energy consumption. The following assumptions have been made for the application.

2.1. The determination of design parameters affecting heating and cooling energy consumption in a building

As the main design parameters are important for determining the indoor thermal comfort and additional energy consumption systems, the decisions taken concerning design parameters for energy efficient heat pump applications are given below;

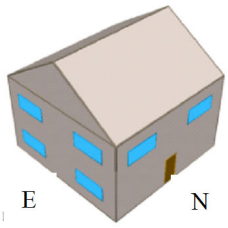
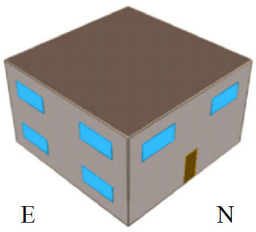
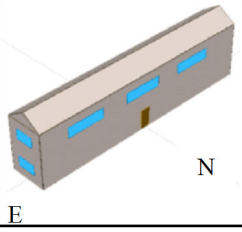
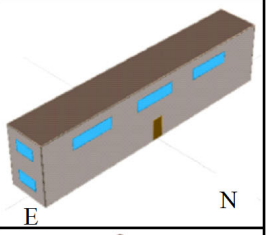
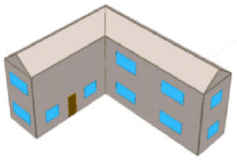
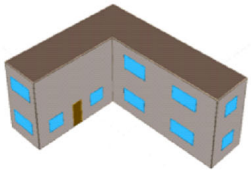
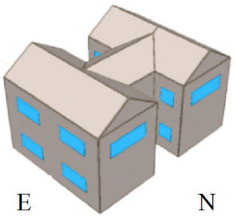
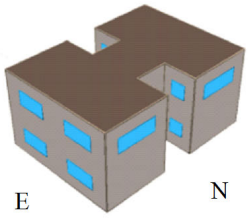
•In this application building on a flat ground are chosen, and the buildings are not shaded by other buildings.

•The proposed methodology is applied for residential buildings with four-person apartment units.

•The proposed methodology is for 4 different buildings with different building forms (square, rectangular, L-shaped and H-shaped). The selected buildings are considered as 2 storeys high, detached with flat or pitched roof as shown

in Table 1. In order to follow their thermal behaviours, selected building forms (square, rectangular L-shaped and H-shaped) are modelled with flat roof and pitched roof without overhang.

Table 1. *3 D images of the buildings used in the application.*

2D	3D Pitched Roof	3D Flat Roof
Square		
Rectangle		
L-shape		
H-shape		

•Each building's floor area is 100 m²; volume is 600 m³ and has a different façade area according to its form. Only L shaped building form and rectangular building form have the same floor area, total exterior façade area and volume.

•Exterior façade areas of the square, rectangular, L-shaped and H-shaped building forms are 240 m², 348 m², 348 m² and 318 m² respectively.

•The occupancy period of the buildings used in the application is considered as from 18:00 to 07:00 on weekdays, 24 hours on weekends. The simulation program takes into account the internal heat gain of the occupants, which come from not only 4 occupants in each apartment unit, but also from the appliances, electronic devices and lighting.

•The external surfaces of the opaque elements are painted in dark colour with the solar radiation absorptivity of ao= 0.70 in cold (Erzurum), and temperate-dry (Ankara) climatic zone, in white colour with the solar radiation absorptivity of ao= 0.40 in hot-dry climatic zone (Diyarbakir).

•The transparency ratios of the building envelopes kept constant as follows: North: 10%, East: 20%, South: 30%, West: 20%

•Window type is double glazed Low-E with wooden sash. Overall heat transfer coefficient of the transparent component is U_window = 1.8 W/m²K.

•In this study, same optical and thermophysical properties of the building envelope are used for all building forms. The details of opaque and transparent elements (external wall, ceiling-flat roof and pitched roof- floor and window) derived for the applications are shown in Table 2.

•The overall heat transfer coefficients of opaque elements are considered less than or equal to the limit values suggested for Ankara, Diyarbakir and Erzurum according to TS 825 (TS 825, 1998). Opaque component alternatives which provide these overall heat transfer coefficients are chosen from the building materials which are produced and commonly used in Turkey

•Air source and vertical loop (ASHP) and ground source heat pump (GSHP) systems are used in the buildings for application.

•Heating set point temperature is determined as 15 ^{0}C (Koçlar, 1991).

•Using bioclimatic comfort chart, seasonal cooling period is determined based on inside air movement speeds required with the effects of outside air

temperature and relative humidity. When the required ventilation rate is over 0,8 m/sec., it is considered that the natural ventilation cannot be achieved and cooling is required (Berköz et al. 1991, Akşit 2002).

•During the occupied period, the comfort value of indoor air temperature is taken as 21^{0}C for heating and as 26^{0}C for cooling according to international standards and Turkish Standard, TS 825 (TS 825, 1998).
•During the unoccupied period, the value of indoor air temperature is taken as 16^{0}C for heating and as 30^{0}C for cooling.
•The coefficient of performance (COP) value is 3,8 for ground source heat pump and 2,72 for air source heat pump
•The energy efficiency ratio (EER) value is 10 for ground source heat pump and 8,08 for air source heat pump
•The depth of heat exchanger for GSHP is 100 m.

Table 2. *Details of building envelope components according to climatic zones.*

Opaque components	Materials	Thicknesss of the material m			Overall heat transfer coefficient Uo (W/m²K) Ankara	Diyarbakır	Erzurum
Wall	Cement mortar	0,02			0,493	0,562	0,395
	Extruded polystyrene foam	A	D	E			
		0,04	0,03	0,06			
	Porous light brick	0,19					
	Lime mortar	0,02					
Ceiling-1	Glass wool	A	D	E	0,283	0,396	0,248
		0,13	0,09	0,15			
	Concrete slab	0,12					
	Lime mortar	0,02					
Ceiling-2	Gravel	0,05			0,291	0,373	0,249
	Felt	0,007					
	Extruded polystyrene foam	A	D	E			
		0,12	0,09	0,13			
	Polymer Bituminous waterproof	0,007					
	Lightweight concrete for slopes	0,08					
	Concrete slab	0,12					
	Lime mortar	0,02					
Floor	Wood	0,02			0,413	0,54	0,369
	Cement finish	0,05					
	Polymer Bituminous waterproof	0,007					
	Extruded polystyrene foam	A	D	E			
		0,06	0,04	0,07			
	Polymer Bituminous waterproof	0,007					
	Lean concrete	0,1					
	Rubble masonary	0,15					
	Ground						
Window					1,80	1,80	1,80

2.2. Calculation of total energy consumption of heat pump systems in the building

All calculations are made with real atmosphere values according to the meteorological data, provided by the Turkish State Meteorological Service. Throughout the application study calculations are made by using a building simulation program, e-QUEST. e-QUEST is a building energy use analysis tool derived from an advanced version of the DOE-2 simulation engine which helps users to perform building energy simulations by considering the state-of-the art building technologies (Url-1). The DOE-2 engine has the ability

to simulate the thermal behavior of spaces in a building, where heat loads, such as solar gain, equipment loads, people loads, lighting loads, and air conditioning systems can be modeled and simulated with the engine.

DOE- 2 is a program designed to explore the energy behavior of proposed and existing buildings and their associated HVAC systems. It employs weighting factors for the calculation of thermal loads and room temperatures. With weighting factor method, an hourly thermal load calculation is performed based on a physical description of the building and that hour's ambient weather conditions. These loads are used, along with the characteristics and availability of heating or cooling systems for the building to calculate air temperatures and heat extraction or heat addition rates (DOE 2 1980, DOE 2 1981, DOE 2 1993, DOE 2 1993).

e-QUEST is a complete interactive Windows implementation of the DOE-2 program with added wizards and graphic displays to aid in the use of DOE-2. e-QUEST calculates hour by hour building energy consumption over an entire year (8760 hours) using hourly weather data for the location under consideration. Inputs to the program consists of a detailed description of the building being analyzed, including hourly scheduling of the occupants, lighting, equipment and thermostat settings. e-QUEST provides an accurate simulation of such buildings features as shading, fenestration, interior building mass, envelope building mass and the dynamic response of different heating and air conditioning system types and controls (Hirsch, 2009).

In the calculation, the amount of energy consumed for efficient operation of the system depending on the air temperature is taken into account. In the simulations, the comfort value of the indoor air temperature for all spaces of the buildings is considered as equal and thus, the effect of the internal walls and floors are neglected. Therefore, for heating and cooling loads calculations, the whole volume of the building is taken into account.

Climatic data for 1 year known as a weather year are required for calculating the building energy demand. Typical Meteorological Year (TMY) file is prepared as 'Hourly Meteorological Year' file for Ankara, Diyarbakır and Erzurum (Url-2, Tavil et al. 1996).

3. Results

Energy consumptions of ASHP and GSHP systems applications for different building forms (square, rectangular, L-shaped, H-shaped) with different roof types (flat roof, pitched roof) are calculated for each climatic zone. Monthly energy consumptions calculated in Ankara, Diyarbakır and Erzurum are expressed in charts where minimum energy consumptions represent the spring season. On the other hand, the heating and the cooling periods can be observed with the increase of energy consumptions (Table 3, Table 4 and Table 5). Climatic parameters like outside air temperature and ground temperature are also shown in the charts in order to evaluate their effects on the performance of heat pumps.

Annual energy consumptions of heat pump systems in different building forms are adjusted from monthly energy consumptions for a better performance evaluation. Annual total energy consumptions of ASHP and GSHP systems used in different building forms which have the same floor area, volume and

optical and thermophysical properties of building envelope are compared for temperate-dry climatic zone (Ankara) in Fig.1, for hot-dry climatic zone (Diyarbakir) in Fig.2, and for cold climatic zone (Erzurum) in Fig.3. An optimum building form and heat pump combination is chosen for every climatic zone.

Table 3. *Annual total energy consumption for Ankara (temperate-dry climatic zone).*

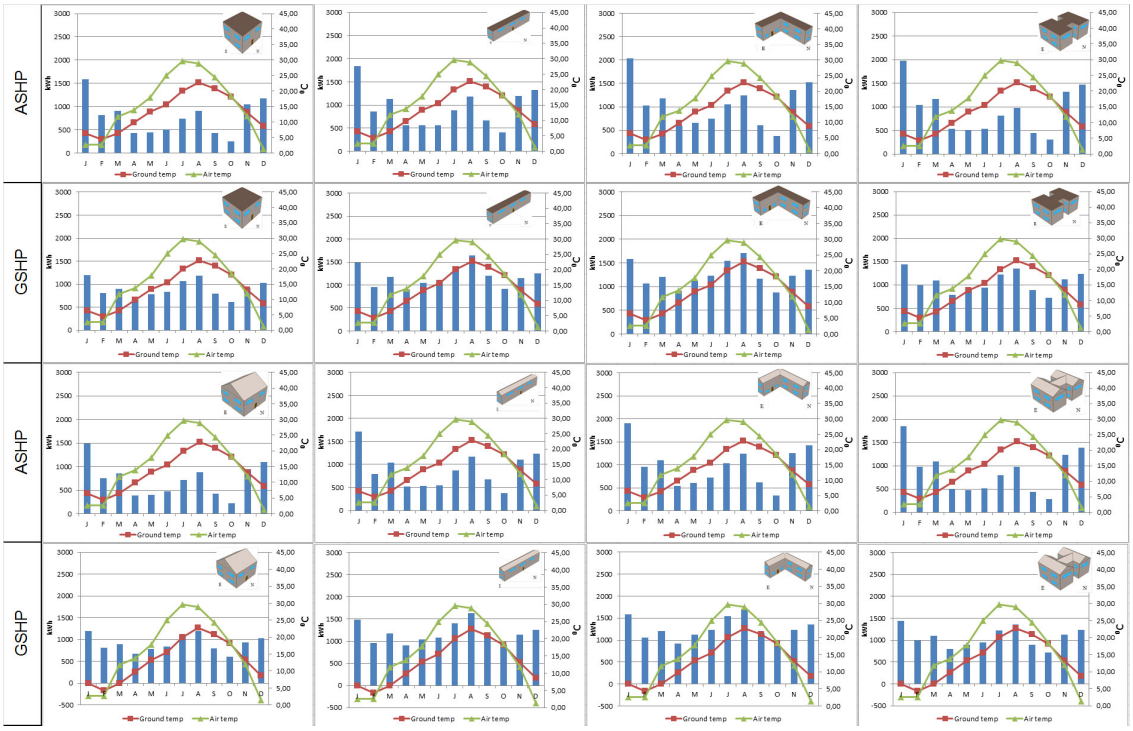


Table 4. *Annual total energy consumption for Diyarbakır (hot-dry climatic zone).*

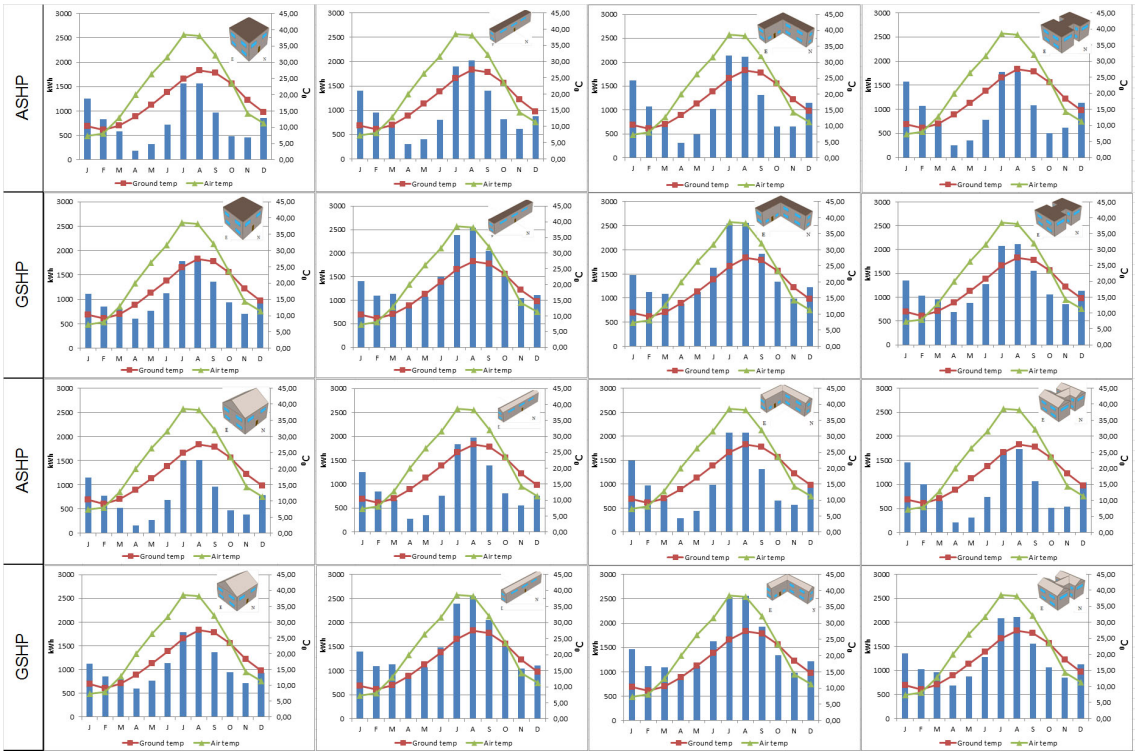
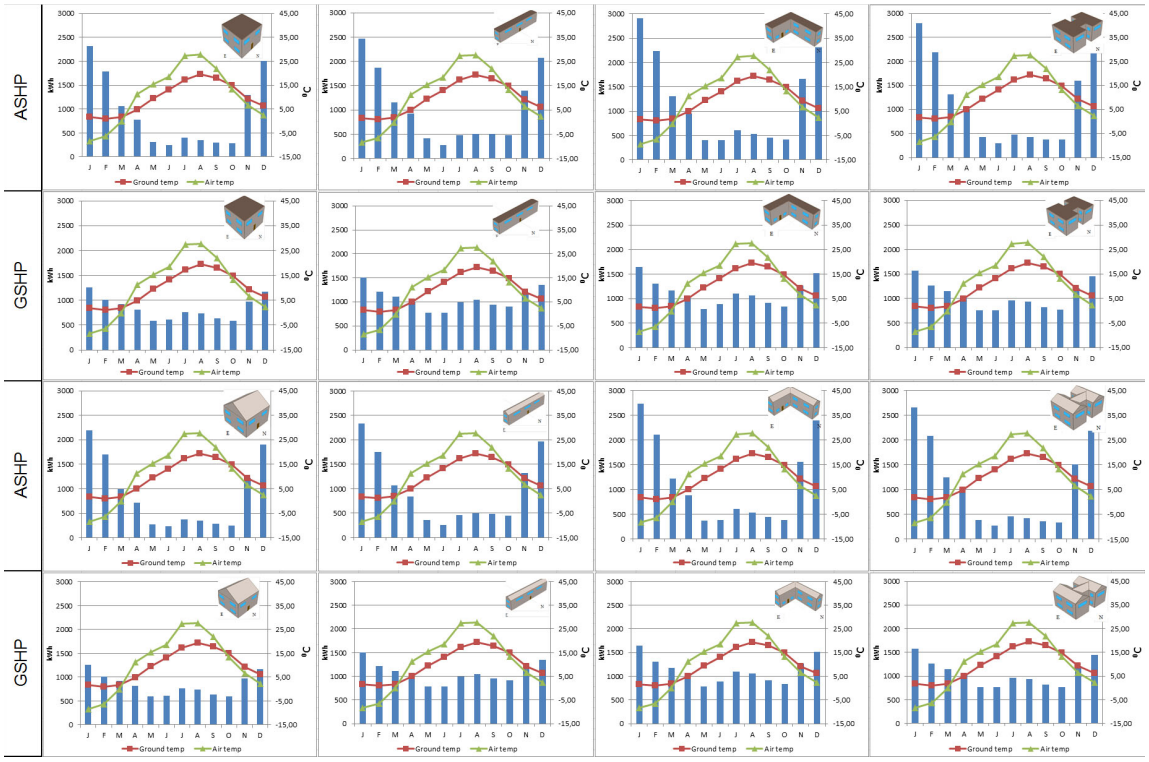


Table 5. *Annual total energy consumption for Erzurum (cold climatic zone).*



After the comparison of calculated values of heat pump applications for different building forms, the results are summarized as follows:

•For the evaluation of monthly energy consumption variations for Ankara, when ASHP systems are used, the energy consumption increases for heating period and decreases for cooling period. On the other hand, when GSHP systems are used in Ankara, energy consumption increases for cooling period and decreases for heating period (Table 3).

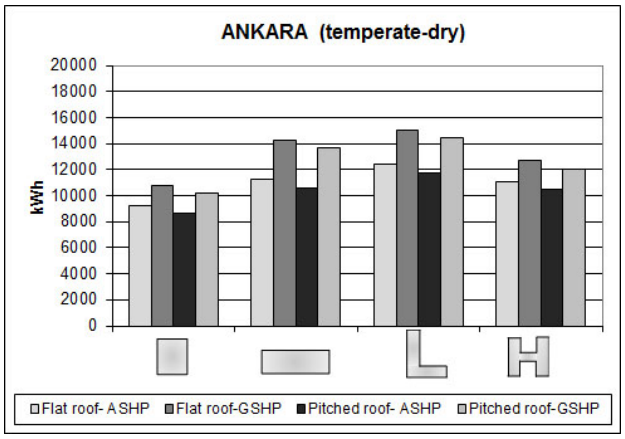


Figure 1. *The comparison of annual energy consumption of ASHP and GSHP systems in square, rectangular, L-shaped and H-shaped building forms for Ankara.*

•As it can be seen in Figure 2, using ASHP systems in Ankara provides the lowest annual energy consumption.

•When ASHP use is compared with GSHP use, annual energy consumption reduces 15% for square form, 22% for rectangular form, 18% for L-shaped form and 13% for H-shaped form in Ankara (Figure 1).

•When evaluating variations in monthly energy consumptions in Diyarbakır, it can be seen that the cooling period is longer than those in Ankara and Erzurum and consequently the cooling loads consumptions are higher. However, when comparing ASHP and GSHP systems, cooling loads decrease with the use of ASHP and the heating loads decrease with the use of GSHP (Table 4).

•As it can be seen in Figure 2, using ASHP systems in Diyarbakır provides the lowest annual energy consumption.

•When ASHP use is compared with the GSHP use, annual energy consumption reduces, 23% for square form, 31% for rectangular form, 25% for L-shaped form and 22% for H-shaped form in Diyarbakir (Figure 2).
•When evaluating variations in monthly energy consumptions in Erzurum, it can be seen that this city has the longest heating period and the shortest cooling period, thus the energy consumptions for the heating period are very high. In Erzurum, when ASHP systems are used, the energy consumption increases for heating period and decreases for cooling period. On the other hand, with the use of GSHP in Erzurum, the energy consumption increases for cooling period and decrease for heating period (Table 5).
•As it can be seen in Figure 3, using GSHP systems in Erzurum provides the lowest annual energy consumption.
•When GSHP use is compared with ASHP with, annual energy consumption reduces, 10 % for square form, 6 % for rectangular and L-shaped building form, and 8 % for H-shaped form in Erzurum (Figure 3).
•When different building forms (square, rectangular, L-shaped and H-shaped) which have the same volume and same floor area are studied, they present different heating and cooling loads (Figure 1, 2 and 3).
•For every climatic zone, square building form presents the lowest annual total load (Figure 1, 2 and 3).
•Comparing average annual loads of square building forms with those of H-shaped, rectangular and L-shaped building form, annual energy consumptions are increased by 19 %, 27 % and 38 % respectively in the temperate-dry climatic zone and 18 %, 33 % and 39 % in the hot and dry climatic zone (Figure 1 and 2).
•For the cold climatic zone, when ranking total energy consumption for each building form, rectangular, H-shaped and L-shaped building forms provide 19%, 24% and 32% more energy consumption respectively, compared with the average annual loads of square building form (Figure 3).

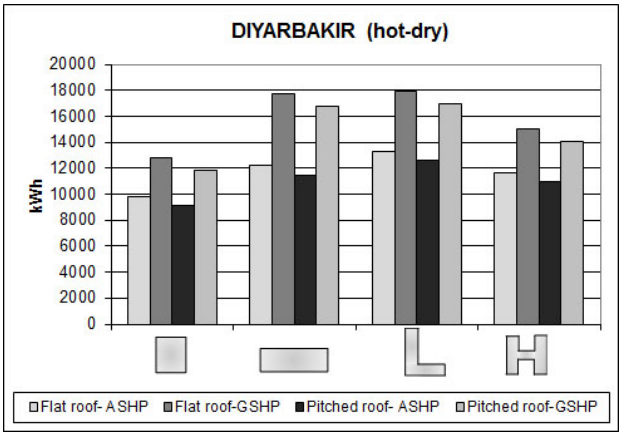


Figure 2. *The comparison of annual energy consumptions of ASHP and GSHP systems in square, rectangular, L-shaped and H-shaped building forms for Diyarbakir.*

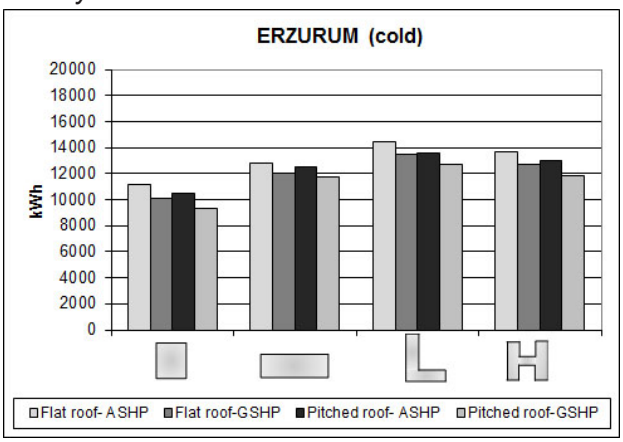


Figure 3. *The comparison of annual energy consumptions of ASHP and GSHP systems in square, rectangular, L-shaped and H-shaped building forms for Erzurum.*

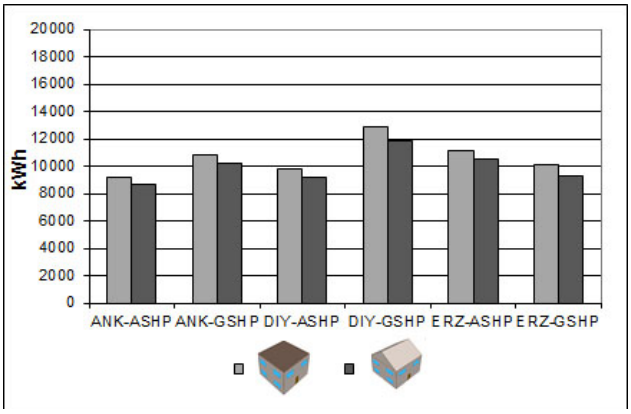


Figure 4. *The comparison of annual energy consumption of flat and pitched roof when ASHP and GSHP systems are used in Ankara, Diyarbakir, Erzurum for square building form.*

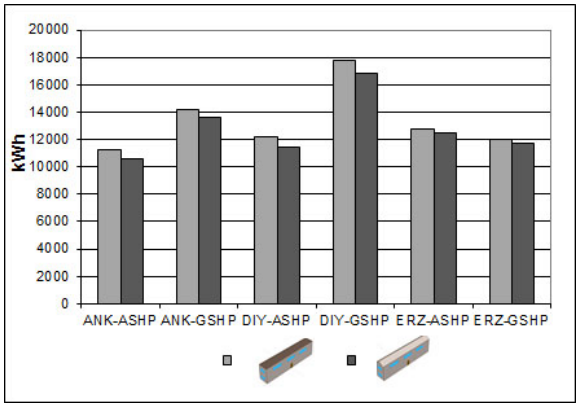


Figure 5. *The comparison of annual energy consumption of flat and pitched roof when ASHP and GSHP systems are used in Ankara, Diyarbakir, Erzurum for rectangular building form.*

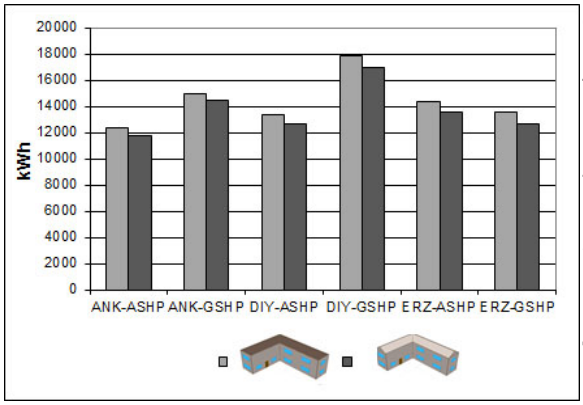


Figure 6. *The comparison of annual energy consumption of flat and pitched roof when ASHP and GSHP systems are used in Ankara, Diyarbakir, Erzurum for L-shaped building form.*

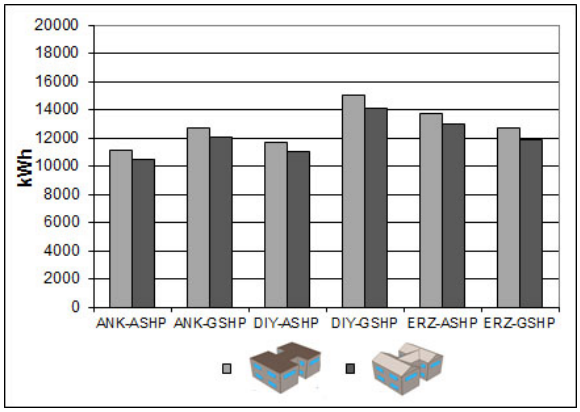


Figure 7. *The comparison of annual energy consumption of flat and pitched roof when ASHP and GSHP systems are used in Ankara, Diyarbakir, Erzurum for H-shaped building form.*

•The results of the study of the roof effect on the annual energy consumption for each building form in different climatic zones are given in Figure 4, 5, 6 and 7.

•For the comparison of the calculation results of the pitched roof and flat roof application for the same building form; the annual heating and cooling energy consumption of pitched roof application is 5 %, 6 %, 5 % lower than the flat roof application in Ankara, Diyarbakir and Erzurum respectively (Figure 4, 5, 6 and 7). The percentage values are computed by taking the average of each difference value.

•In all calculations, the annual energy consumption of rectangular building form is 9-10 % less than the energy consumption of L shaped building form as seen in Figures 5 and 6. The difference between the annual energy consumptions of L shaped building form and rectangular building form which have the same floor area, total exterior façade area, volume, roof type and optical and thermo physical properties of building envelope are caused due to the fact that they have the same transparency ratio but different façade areas oriented to the same direction (Erdim &Manioğlu, 2011).

4. Conclusions

Heating and cooling energy consumptions can be controlled when important energy defining design decisions are made during the design phase in order to provide climatic comfort and energy conservation in buildings. With an integrated design process, the design parameters such as building form, building envelope and location of the building which have an important role on the energy consumption of the building contribute more to energy efficient heat pump applications.

The method which is introduced in this paper is used to determine the building form and heat pump system combinations which provide the climatic comfort conditions with the minimum energy consumption in different climatic zones. The methodology enables us to select optimum building form in different climatic zones for energy efficient heat pump systems which ensure minimum energy consumption without changing the values of other design parameters in the design process. The results of this application are summarized below.

•The square building form which has the smallest exterior façade area provides the minimum heating and cooling energy consumption in every climatic zone as expressed in former published studies.
•Different building forms with different exterior façade areas present different annual energy consumptions even if they have the same volumes.
•Although they may have the same floor area, the same total exterior façade area, the same volume, roof type, the same optical and thermophysical properties of the building envelope, the annual energy consumption of buildings varies upon different forms they may have.
•Energy consumptions of different heat pump applications in different climatic zones depend on the heating and the cooling period duration and intensity. Therefore selection of the right heat pump application for a chosen building form is only possible by taking into consideration the climatic conditions of the region.
•The roof type which is a component of the building form and the façade areas oriented to different directions have an important effect on the annual energy consumption.

Therefore, in order to evaluate the impacts of building design parameters in different climatic zones on energy efficient heat pump applications, the proposed methodology should be applied step by step for each different type of building even the building forms have the same floor area, total exterior façade area, volume and optical and thermophysical properties of building envelope. As a result of this, the building form and heat pump combination which has the lowest annual heating and cooling energy consumption should be chosen.

This study shows that energy efficient heat pump application is possible for different building forms with the developed approach under different climatic conditions. In other words, this proposed methodology allows us to quantify the impact of different design parameters on the need for energy conservation. However, in this study, a limited number of building form and heat pump combination alternatives are discussed for Ankara, Diyarbakir and Erzurum region. The assumptions made for this application can be modified according to the parameters of any building and the climatic conditions of any region under consideration. Thus, the method can be applied to any region and to any building to determine the optimum building form and heat pump application in terms of energy conservation. Repeating the calculations of the proposed method for other climatic regions and for all possible combinations of the design parameters, the most appropriate architectural solutions for energy efficient design can be obtained.

Although a general recommendation for the best heat pump application for different climatic region cannot be given in the present work, this approach is shown to be capable of giving clear insights on the relationships between energy, building form, climatic condition and heat pump performance which are four crucial parameters to estimate the final energy consumption.
The suggestions about approach in order to contribute to future studies are as follows,
•Heat losses and gains with different exterior façades can be examined in more detail by simulating different dimensions in each building form.
•The approach can be developed by taking into consideration the parameters such as initial investment costs and life cycle costs.
•The approach can be applied to the existing building forms during renovation

by proposing appropriate values for the design parameters such as building envelope, roof type and heat pump type, thus it will be possible to provide energy efficiency in an existing building.

In conclusion, in order to provide climate comfort with minimum energy in buildings, it is possible to determine optimum values for the building design parameters in the early design stage with the use of heating and cooling systems.

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Farklı iklim bölgeleri için enerji etkin ısı pompası uygulamalarında bina formunun etkisi

Enerji bakımından diğer ülkelere bağımlı hale gelen ülkemizde tüketilen enerjinin büyük bir bölümü binaların ısıtılmasında ve soğutulmasında kullanılmaktadır. Binalarda enerji korunumu ve iklimsel konfor sağlanması gerekliliği karşısında en önemli görev, inşaat ve kullanım aşamasında minimum enerji gerektirecek ve aynı zamanda iklimsel konfor koşullarını sağlayabilecek bir yapma çevre tasarlamaktır.

Birincil enerji kaynakları bakımından yeterli kapasitesi olmayan ülkemizde, tükettiğimiz enerjinin büyük bir bölümü ithal edilmekte ve enerji bakımından diğer ülkelere daha da bağımlı hale gelinmektedir. Binaların ısıtılmasında ve soğutulmasında kullanılan enerji miktarı ise, toplam tüketilen enerjinin %85`ini oluşturmaktadır. Son yıllarda ise doğal kaynakların tükenmesi, çevre kirliliğinin artması ve insan sağlığını bozan düzeye ulaşması gibi etkenler yüksek enerji harcamalarının görüldüğü konut sektöründe, mekanik ısıtma ve soğutma sistemlerinin enerji harcamalarının minimum düzeye indirgenmesini zorunlu kılmaktadır.

Mekanik ısıtma ve soğutma sistemlerinde kullanılan sıvı ve fosil yakıt gibi enerji kaynaklarının yetersiz ve pahalı oluşu, bu enerji kaynaklarının çevreye kirlilik yayması ve insan sağlığını tehdit edecek düzeye ulaşması sonucunda, binalarda enerji tüketiminin minimum düzeyde tutulması için pasif sistemlerle birlikte, güneş, rüzgâr, biyokütle ve çevre enerjileri gibi alternatif enerji kaynaklarını kullanan ve binaya sonradan entegre edilen aktif sistemlerin (güneş kollektörleri, güneş pilleri, rüzgar tribünleri vb.) kullanımı bir zorunluluk haline gelmiştir.

1970`li yıllarda petrol krizi sırasında yaygın kullanımına geçilen ısı pompaları, enerji korunumunu sağlamak ve CO_2 emisyonlarını azaltarak çevre kirlenmesine neden olmadan endüstriyel ve günlük uygulamalarda kullanılabildiği için son yıllarda üzerinde yoğun çalışmalar yapılan bir konu haline gelmiştir. Mekanik ısıtma ve soğutma sistemleri olarak kullanılan ısı pompaları kaynaklarına göre yer, su ve hava kaynaklı olarak sınıflandırılmaktadır. Isı pompası kullanımında ısıtma ve soğutma için gerekli enerjinin ¾ ünü çevreden almakta ve geri kalanını ise tahrik enerjisi olarak elektrik

akımından temin etmektedir. Çevre enerjisini kullanan ısı pompalarıyla, toprağın, havanın, yeraltı ve yüzey suyunun enerjisinden faydalanılarak binalarda kışın ısıtma, yazın ise soğutma sağlanabilmektedir. Yazın mekândan alınan ısı, ısı pompası yardımıyla toprağa, havaya, yeraltı veya yüzey suyuna aktarılırken, kışın mekânı ısıtmak için gerekli ısı, ısı pompası vasıtasıyla topraktan, havadan, yeraltı veya yüzey suyundan çekilebilmektedir.

Yılın belirli dönemlerinde dış iklim koşullarındaki değişiklikler nedeniyle, pasif sistemlerle konfor koşulları belirli sınırlara kadar sağlanabilmekte ve bu sınırların ötesinde binalarda mekanik ısıtma ve soğutmaya gerek duyulabilmektedir. Mekanik ısıtma ve soğutma harcamalarının beraberinde yüksek enerji maliyeti ve çevre kirliliği gibi problemler getirdiği bilinmektedir. Mekanik ısıtma ve soğutma sistemlerine ihtiyaç duyulması sonucu, bu sistemler tarafından kullanılacak enerji miktarı, yapıların pasif sistemler olarak ne kadar başarılı tasarlandığına bağlıdır. Bu nedenle, binaya ait tasarım değişkenlerine ilişkin kararların, mekanik ısıtma ve soğutma sistemlerinin enerji harcamalarına en az yük getirecek şekilde alınması gerekmektedir. Isıtma ve soğutma enerji harcamalarını etkileyen en önemli tasarım değişkenleri; binanın yeri, binanın formu, binanın yönlendirilişi ve bina kabuğunun optik ve termofiziksel özellikleri olarak sıralanabilir. Yöresel iklimsel koşulların şiddetine bağlı olarak bina formu; taban alanları ve iç hacimleri aynı fakat farklı formlardaki binalarda, kabuk elemanının alanları ve yönlendiriliş biçimleri farklı olacağından, kabuk elemanından geçen ısı miktarına bağlı olarak toplam ısı kayıp ve kazançlarını, dolayısıyla mekanik ısıtma ve soğutma sistemlerinin enerji harcamalarının miktarını belirler. Dolayısıyla binaya ilişkin tasarım değişkenleri birbirlerini de etkileyerek yıllık toplam enerji harcamalarının belirlenmesinde önemli bir rol oynar.

Bu çalışmada, binalarda enerji korunumu ve iklimsel konfor sağlanması amacıyla mekanik ısıtma ve soğutma sistemleri olarak kullanılan ısı pompalarının enerji harcamalarını, tasarım aşamasında binaya ilişkin tasarım değişkenleri için alınan kararlar yardımıyla kontrol altına almayı hedefleyen bir yaklaşım geliştirilmiştir. Bu amaçla; taban alanları, iç hacimleri ve bina kabuğu optik ve termofiziksel özellikleri aynı olan farklı dört bina formu için (kare, dikdörtgen, L ve H formu), toprak ve hava kaynaklı ısı pompasının yıllık toplam ısıtma ve soğutma enerji harcamaları, bir bina simülasyon programı olan e-QUEST programı yardımı ile hesaplanmıştır. Hesaplamalar sonucunda, bina formlarına ait yıllık toplam ısıtma ve soğutma enerji harcamaları değerlendirilmiş ve;
•Minimum dış cephe alanına sahip olan kare bina formunun en düşük ısıtma ve soğutma harcamalarını gerçekleştirdiği,
•Aynı taban alanı, aynı dış cephe alanı, aynı iç hacime sahip olsalar bile aynı yönlere bakan farklı cephe alanları nedeniyle güneş ışınımından elde edilen farklı ısı kayıp ve kazançları sonucu farklı bina formlarında yıllık enerji harcamalarının değişim gösterdiği,
•Farklı iklim bölgelerindeki farklı ısı pompası uygulamalarında gerçekleşen enerji harcamalarının bölgenin ısıtma ve soğutma dönemlerinin yoğunluğuna bağlı olarak değişkenlik gösterdiği, dolayısıyla doğru ısı pompası seçiminin iklim bölgesine bağlı olarak gerçekleşebileceği ve
•Bina formunun bir bileşeni olan çatı tipinin enerji harcamalarında etkin olduğu
sonuçları elde edilmiştir.

Geliştirilen yaklaşım farklı iklim bölgeleri için adım adım uygulandığında, en düşük yıllık enerji harcamalarını gerçekleştiren bina formu ve ısı pompası kombinasyonunu seçmek olanaklıdır. Bir başka deyişle geliştirilen yaklaşım yardımıyla farklı tasarım değişkenlerinin niceliksel etkisi ölçülebilmekte ve binalarda enerji korunumuna katkıda bulunulmaktadır.